REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
15-01-2014	Quarterly Report	1-8-2013 to 31-12-2013

4. TITLE AND SUBTITLE

HullBUG Technology Development for Underwater Hull Cleaning Quarterly Report

5a. CONTRACT NUMBER

N00014-09-C-0852

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Ben Lovelace, Don Darling

5d. PROJECT NUMBER

09PR0914-00 & 01

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

SeaRobotics
7721 SE Ellipse Way
Stuart, FL 34997

8. PERFORMING ORGANIZATION REPORT NUMBER

Quarterly Report 1-15-2014
N00014-09-C-0852 Rev A.pdf

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Mr. Stephen W. McElvany, ONR Code 332
Office of Naval Research
875 N Randolph St.
Arlington, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)

ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Unclassified/Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Hull Bio-Mimetic Underwater Grooming (HullBUG) Vehicle System under development holds the potential to dramatically change current hull cleaning methods and their environmental impacts. Frequent use of the HullBUG, a small autonomous cleaning device, on the hulls of Navy ships in port by applying light cleaning pressure or grooming results in a cost effective solution to the underwater fouling problem.

As part of overall HullBUG development the Grooming Tool requires particular attention. This tool and variations of it have been used by Florida Institute of Technology (FIT) during several years of testing activities. FIT was assigned the task to come up with a set of parameters that FIT would want in the next generation tool. SeaRobotics was assigned the task of developing a grooming tool that would address those parameters. After review by Navy and FIT personnel the agreed to design would be built and tested. This report documents that effort.

15. SUBJECT TERMS

HullBUG, Grooming Tool, Underwater hull cleaning, autonomous vehicle

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Ben Lovelace
U	U	U	UU	10	19b. TELEPHONE NUMBER *(Include area code)* 561-627-2676

Reset

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

INSTRUCTIONS FOR COMPLETING SF 298

1. REPORT DATE. Full publication date, including day, month, if available. Must cite at least the year and be Year 2000 compliant, e.g. 30-06-1998; xx-06-1998; xx-xx-1998.

2. REPORT TYPE. State the type of report, such as final, technical, interim, memorandum, master's thesis, progress, quarterly, research, special, group study, etc.

3. DATES COVERED. Indicate the time during which the work was performed and the report was written, e.g., Jun 1997 - Jun 1998; 1-10 Jun 1996; May - Nov 1998; Nov 1998.

4. TITLE. Enter title and subtitle with volume number and part number, if applicable. On classified documents, enter the title classification in parentheses.

5a. CONTRACT NUMBER. Enter all contract numbers as they appear in the report, e.g. F33615-86-C-5169.

5b. GRANT NUMBER. Enter all grant numbers as they appear in the report, e.g. AFOSR-82-1234.

5c. PROGRAM ELEMENT NUMBER. Enter all program element numbers as they appear in the report, e.g. 61101A.

5d. PROJECT NUMBER. Enter all project numbers as they appear in the report, e.g. 1F665702D1257; ILIR.

5e. TASK NUMBER. Enter all task numbers as they appear in the report, e.g. 05; RF0330201; T4112.

5f. WORK UNIT NUMBER. Enter all work unit numbers as they appear in the report, e.g. 001; AFAPL30480105.

6. AUTHOR(S). Enter name(s) of person(s) responsible for writing the report, performing the research, or credited with the content of the report. The form of entry is the last name, first name, middle initial, and additional qualifiers separated by commas, e.g. Smith, Richard, J, Jr.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES). Self-explanatory.

8. PERFORMING ORGANIZATION REPORT NUMBER. Enter all unique alphanumeric report numbers assigned by the performing organization, e.g. BRL-1234; AFWL-TR-85-4017-Vol-21-PT-2.

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES). Enter the name and address of the organization(s) financially responsible for and monitoring the work.

10. SPONSOR/MONITOR'S ACRONYM(S). Enter, if available, e.g. BRL, ARDEC, NADC.

11. SPONSOR/MONITOR'S REPORT NUMBER(S). Enter report number as assigned by the sponsoring/ monitoring agency, if available, e.g. BRL-TR-829; -215.

12. DISTRIBUTION/AVAILABILITY STATEMENT. Use agency-mandated availability statements to indicate the public availability or distribution limitations of the report. If additional limitations/ restrictions or special markings are indicated, follow agency authorization procedures, e.g. RD/FRD, PROPIN, ITAR, etc. Include copyright information.

13. SUPPLEMENTARY NOTES. Enter information not included elsewhere such as: prepared in cooperation with; translation of; report supersedes; old edition number, etc.

14. ABSTRACT. A brief (approximately 200 words) factual summary of the most significant information.

15. SUBJECT TERMS. Key words or phrases identifying major concepts in the report.

16. SECURITY CLASSIFICATION. Enter security classification in accordance with security classification regulations, e.g. U, C, S, etc. If this form contains classified information, stamp classification level on the top and bottom of this page.

17. LIMITATION OF ABSTRACT. This block must be completed to assign a distribution limitation to the abstract. Enter UU (Unclassified Unlimited) or SAR (Same as Report). An entry in this block is necessary if the abstract is to be limited.

HULLBUG TECHNOLOGY DEVELOPMENT FOR UNDERWATER HULL CLEANING

QUARTERLY REPORT

EMPHASIS ON GROOMING TOOL

PREPARED BY:

BEN LOVELACE
SEAROBOTICS
7721 SW ELLIPSE WAY
STUART, FL 34997

1/15/14

Contents

I. Contract Information

Contract Number	N00014-09-C-0852
Title of Research	HullBUG Technology Development for Underwater Hull Cleaning
Principal Investigator	Don Darling
Organization	SeaRobotics

II. Technical Section

A. Technical Objectives

The Hull Bio-Mimetic Underwater Grooming (HullBUG) Vehicle System under development holds the potential to dramatically change current hull cleaning methods and their environmental impacts. Frequent use of the HullBUG, a small autonomous cleaning device, on the hulls of Navy ships in port by applying light cleaning pressure or grooming results in a cost effective solution to the underwater fouling problem. The frequency of grooming is selected based on the hull coating and the local fouling pressure on the docked ships or ships at anchor. Frequent grooming prohibits the development of mature fouling colonies and limits fouling to a manageable bio-film layer.

As part of overall HullBUG development the Grooming Tool requires particular attention. This tool and variations of it have been used by FIT during several years of testing activities. FIT was assigned the task to come up with a set of parameters that FIT would want in the next generation tool. SeaRobotics was assigned the task of developing a grooming tool that would address those parameters. After review by Navy and FIT personnel the agreed to design was built and will now be tested.

B. Technical Approach

Upon receipt of FIT provided parameters SRC would take these parameters and propose a mechanical configuration that met them along with the electrical requirements to power the new Grooming Tool. A conceptually designed SolidWorks model would be generated to better understand the packaging and mounting of the tool on the FIT vehicle. Motors and controllers would be sized for the expected loads and incorporated into the solid model. After review by Navy and FIT personnel the model would be refined and updated. Once approved, detailed drawings of the Grooming Tool would be generated. These drawings would be vended out to approved vendors for quoting. Quotes would be obtained for different levels of production in order to better understand the savings associated with buying more. Once a good pricing model was developed and quantity purchased determined, parts would be vended out and manufactured. These parts would then be assembled at SRC. A test program would then follow to fully qualify the design.

C. Progress Summary

Development efforts to date have emphasized the need to provide a stronger acting and more compliant Grooming Tool. To that end it was determined that a new Grooming Tool would be designed, technically reviewed, constructed and tested.

The following sections summarize the project's current status:

1. FIT Supplied Parameters

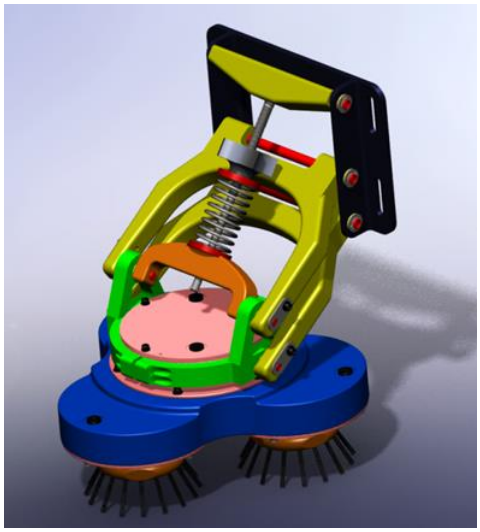
Based on grooming tool studies, FIT has developed a set of specifications that will be the basis of future grooming tool research. More power, more speed and optimal brush to brush center locations were the dominant themes. The following specs were provided by FIT as guidance for future Grooming Tool design.

- 1000 RPM
- 240 mNm per brush
- 12 cm center to center distance

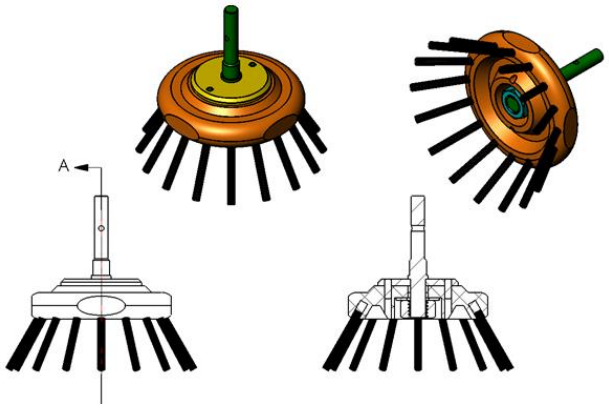
2. Current Design

After discussion and design review the current version of the 3 headed Grooming Tool design consists of a 90 watt motor-flat brushless DC “outrunner” style motor coupled to 3 sets of gears, each providing a 1.75 to 1 gear reduction to the brush head. The motor has been repackaged with a more robust bearing set. Each grooming tool shaft is provided with its own set of bearings and seals. The brushes are mounted to the shaft with a commercially accepted bolting arrangement that allows quick change out of the brushes.

A compliant mount was devised that provides near constant vertical force across the full range of travel.



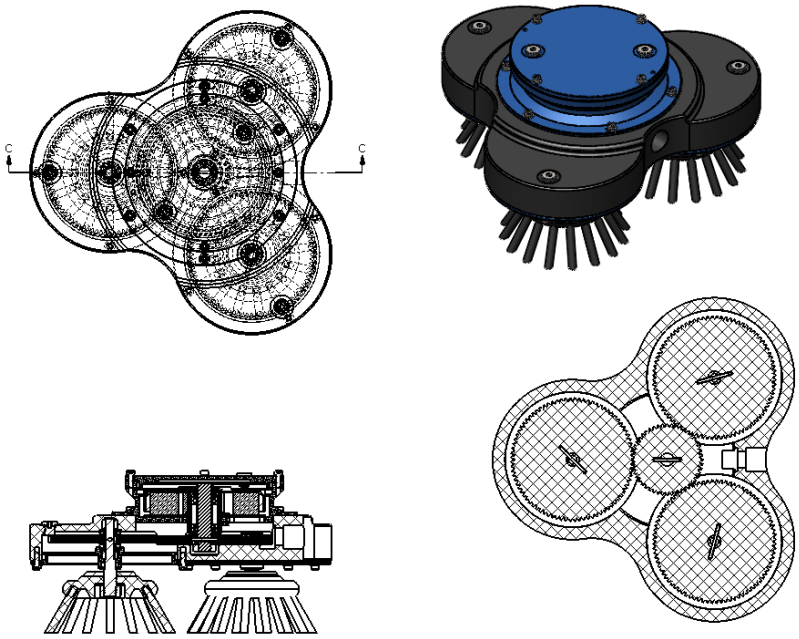
Updated 3 Head Grooming Tool Concept and Compliant Mount



Brush Holder Mount

3. SRC Detailed Design

All of the parts for the 3 headed tool were detailed, dimensioned and tolerances added . A top assembly drawing was created that identified all machined parts as well as all purchased hardware



Top Assembly

4. Grooming Tool Production

Based on total cost, a decision was made to make 1 grooming tool and 1 compliant mechanism. These parts are to be assembled and tested before building more units. Several pictures taken during the assembly process along with the fully assemble items are shown below.

Inner Gear Case with Sun Gear

Planet Gear

Stationary Stator

Rotor with Permanent Magnets

Bottom View of Grooming Tool with Brushes

Top View of Grooming Tool and Compliance Mechanism

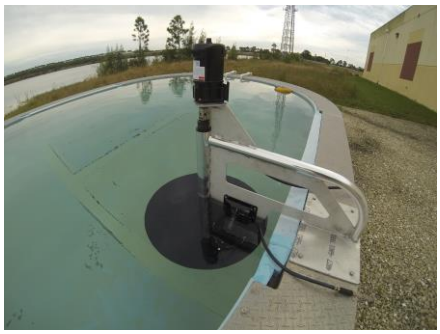
5. Testing Strategy

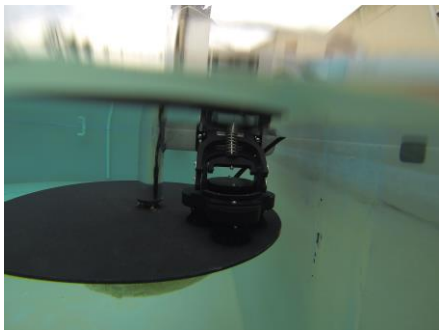
After general review of several different production and testing strategies it was determined that a single 3 headed Grooming Tool and Compliance Mechanism be constructed for extended testing at SRC. A dedicated rotating disk type testing mechanism would be designed and constructed. Functionally, the disk rotating underwater would allow the Grooming Tool to run continuously over a constantly moving surface. The rotating disk could be painted with more than one different coating allowing the grooming tool to run over different coatings in one revolution of the disk. In this way the grooming tool and compliance mechanism would be endurance tested. The wear resistance of the paint would be tested at the same time. Making the testing even more realistic, bumps and divots could be added simulating the varying surfaces found on a ship hull. This constantly rotating device could run virtually unattended for long periods and work to qualify the Grooming Tool, compliance mechanism, the brushes as well as the paint they are designed to groom.

6. Test Fixture Design and Fabrication

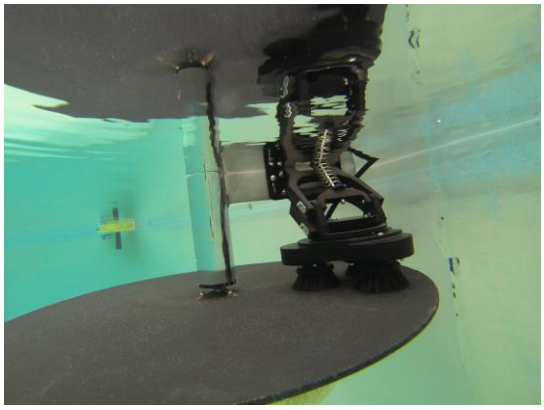
Based on conceptual design parameters a test fixture was designed and fabricated to replicate the movement of the HullBug vehicle at various speeds. A variable frequency drive was chosen to control a 3 phase electric motor to provide variability between minimum and maximum speeds. The following speed limits were determined to be the outer bounds of any reasonable HullBug operating speed.

Minimum Disk 3.6 RPM	Equivalent HullBug transit velocity	10 cm/s
Maximum Disk 18 RPM	Equivalent HullBug transit velocity	50 cm/s





Underwater Test GT Test Fixture



Test Fixture and Grooming Tool on Rotating Disk

Test Fixture Motor Drive under Construction

III. Near Term Priorities

A. Begin Testing

Develop a test plan and start testing of the grooming tool under simulated conditions utilizing the Rotating Disk Test fixture. Start with the simplest configuration and add variations as nominal operation is proven acceptable.

B. Develop Surface Variations to Test

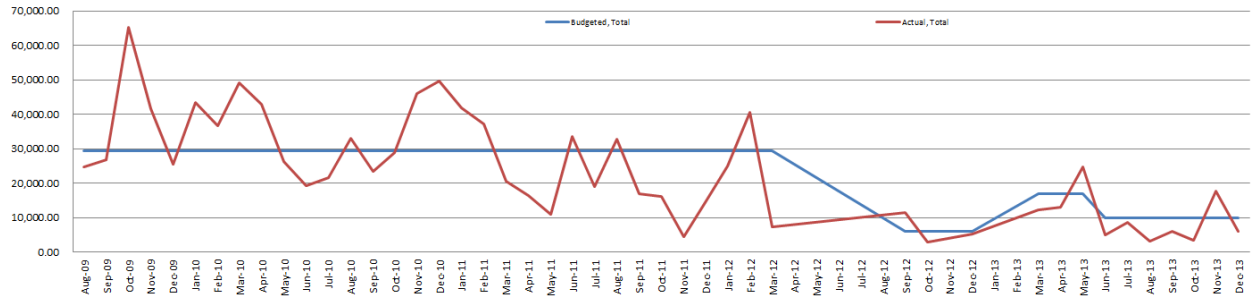
A ship's hull is not flat and contains many humps, bumps, divots and bows in otherwise flat steel that the HullBug must transit over. The simple flat disk simulates movement of the

grooming tool in the simplistic test case. After the simplistic test is proven acceptable the surface of the flat disk should be modified to more closely approximate the uneven surface of a real ship.

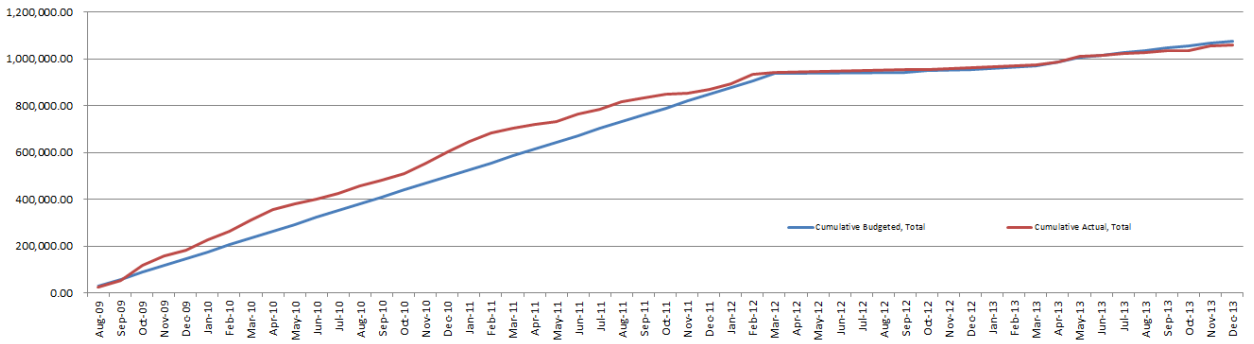
IV. Financial

The following charts and graphs detail the expenditures to date.

Major Cost Elements		Amount for Current Period Billed	Prior Billings	Cumulative Amount From Inception to Date of This Billing
Direct Labor		1,935.61	459,899.42	461,835.03
Onsite Overhead Rate	57.11% of Direct Labor	$ 1,105.43		
Direct Material		$ 1,277.33	89,440.27	90,717.60
Travel		$ 14.43	4,536.50	4,550.93
Subcontracts		$ -	-	0.00
Total Direct Costs		$ 4,332.80	791,166.03	795,498.83
General and Administrative	28.71% of Direct Costs	$ 1,243.95	209,054.92	210,298.87
Total Costs		$ 5,576.74	1,000,220.96	1,005,797.70
Fix Fee Earned	6.00% of Total Costs	$ 334.60	60,012.59	60,347.19
Contract Reserves and Adjustments				
Contract Costs Withheld		$ -	-	-
Fixed Fee Withheld (10% of fee)	0.60% of Costs Withheld	$ 33.46	5,967.36	6,000.82
Adjusted Amounts Claimed				
Current and Cumulative Costs		$ 5,576.74	1,000,220.96	1,005,797.70
Fixed Fee Billed		$ 301.14	54,045.23	54,346.37
	Total BVN-0057	$ 5,877.89	1,054,266.20	1,060,144.08



Monthly Spend Rate



Accumulated Spending